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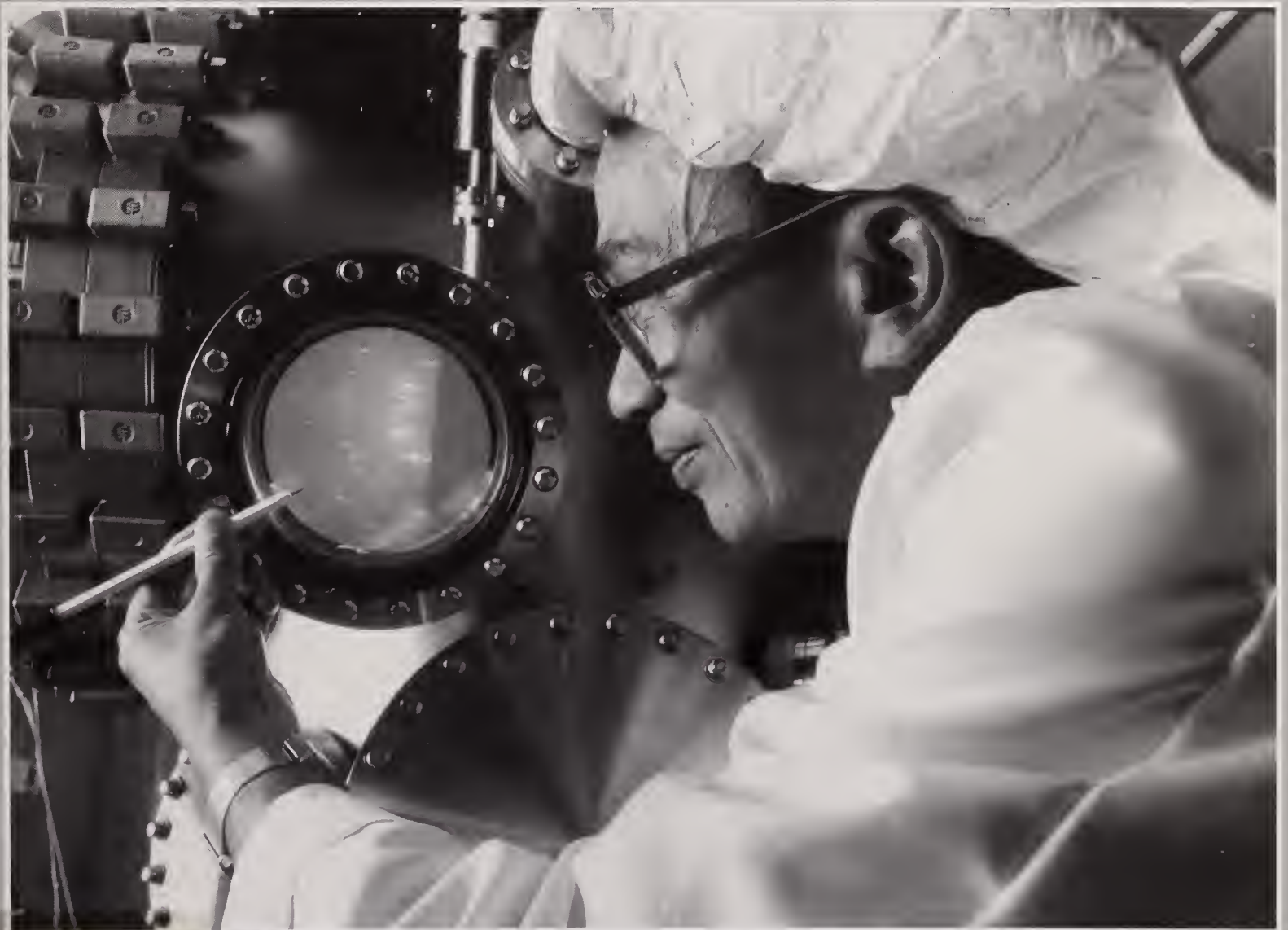
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# NIST Research Reports



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National Institute of Standards and Technology  
NIST Special Publication 783

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On the cover: NIST materials research engineer Wen Tseng uses molecular beam epitaxy to grow and study the properties of thin films of semiconductor compounds such as gallium arsenide and aluminum gallium arsenide. For more on NIST semiconductor research, see the article on page 16.

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# NIST Research Reports

U.S. DEPARTMENT OF COMMERCE  
Robert A. Mosbacher, Secretary

National Institute of Standards  
and Technology  
John W. Lyons, Director

National Institute of Standards  
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# Research Update

## Calibrating the Space Telescope

NIST researchers provided a suite of state-of-the-art radiometric calibrations for the Hubble Space Telescope (HST). Because everything discovered by astronomy depends on analyzing light from distant stars and exotic objects, extremely accurate instrument calibrations are essential to the space telescope mission. NIST scientists aided in the design of a special optical simulator to test the HST faint object spectrograph and calibrated the simulator for brightness. They then calibrated the special light sources used to test the overall sensitivity of the telescope's optics and measuring instruments. In addition, the researchers provided special wavelength and brightness calibrations for an on-board standard lamp, part of the HST high-resolution spectrograph. The latter will make it possible to identify the particular element associated with individual spectral lines, to estimate the speed of the element to within a kilometer per second, and to account for any changes in instrument calibrations while in space. NIST is the only source in the world for radiometric calibrations of short-wavelength vacuum ultraviolet radiation, which are essential for space-based astronomy.

## Using the Space Telescope

Two NIST scientists at the Joint Institute for Laboratory Astrophysics (JILA) have obtained observing time on the Hubble Space Telescope. Jeffrey Linsky, an astronomer and co-investigator on the Goddard high-resolution spectrograph instrument, will make high-precision measurements of the deuterium-to-hydrogen ratio for interstellar gas, an important test of some models of the origin of the universe. He will also study six stars of very low mass to learn whether they have at-

mospheres that resemble the Sun's—such stars are too faint to observe from Earth and can be studied only from space. David Hummer, an astrophysicist, will work with colleagues at JILA and the University of Munich to measure the ultraviolet spectrum of hot stars in the Magellanic Clouds, the galaxies nearest to our own. With these data they will be able to study the origin and evolution of these stars which, unlike stars in our own galaxy, appear to contain a much lower abundance of elements heavier than hydrogen. JILA is a joint operation of NIST and the University of Colorado and is located on the university's campus in Boulder, Colo.

## NIST, 3M Sign Optical Fiber Sensor Research Agreement

NIST and the 3M Company have begun a cooperative program to develop components for optical fiber current sensors. These electric current sensors have potential applications in the electric power industry, electromagnetic pulse and interference testing, and general electronic instrumentation. Having no electrical parts, fiber current sensors are especially attractive in applications where current must be measured at high voltage or in the presence of electromagnetic interference. NIST has developed certain technologies in this field, including methods for improving the properties of fiber coils for sensing. A guest scientist from the 3M Fiber Optics Laboratory in St. Paul, Minn., will spend a year working with researchers at the NIST Boulder laboratories. NIST will share its knowledge with 3M, and the visiting 3M scientist will participate in further developmental work in fabrication, packaging, and characterization of the coils.

## Narrowest Spectral Line Produced

NIST researchers have made the narrowest known observation of an optical spectral line. To do it, they developed the narrowest linewidth laser ever produced. Their work represents a big step toward an optical frequency time standard that would be 10,000 times more accurate than the best current standard (based on a microwave-range frequency of the cesium atom). For a variety of reasons, a time standard in the optical frequency range would be very useful, and the more narrow the observed line, the more accurate the standard.

The NIST researchers isolated a single, laser-cooled mercury ion in an electromagnetic trap and probed it with the newly designed laser with an effective linewidth of about 86 Hz at a wavelength of 563 nanometers. The frequency observation was more than 10 times narrower than any previous such attempt. A time standard based on such a system could be accurate to a part in  $10^{18}$ , compared with the current standard, which is accurate to a part in  $10^{13}$ . For a copy of paper no. 13-90 describing this work, contact Jo Emery, Div. 104, NIST, Boulder, CO 80303, 303/497-3237.

## Ten Agencies Using NIST, Treasury System for EFT

A system designed by NIST and the Department of the Treasury now is being used for electronic funds transfers (EFT) by 10 federal agencies. The system allows federal agencies to request electronically disbursement of funds from the Treasury and allows the Treasury to safely and quickly make the payments requested by the agencies. Previously,

requests were mailed from the agencies to Treasury financial centers. Over the past several years, NIST researchers have been working with the Treasury to help protect electronic funds transfers. They have developed test methods to validate that devices used to authenticate financial messages correctly implement federal and industry standards. They also developed a test to validate systems that distribute the keys needed to scramble or unscramble the electronic messages. Over the next 2 years, 300 government sites are expected to implement the new disbursement system.

## **Upgraded Program Aids Police Vehicle Selection**

Police fleet managers seeking economy and appropriate features can use the latest version of AutoBid, a computer software program that grades potential fleet acquisitions on a variety of performance parameters. The program incorporates test scores published annually by the Michigan State Police Department on the dynamics, acceleration, speed, braking, ergonomics, and fuel economy of vehicles. It helps users combine these scores with bid prices to determine the lowest cost for needed performance.

Developed at NIST, AutoBid (Version 2.0) is the first major upgrade to the original NIST-created AutoBid program now used in over 450 police departments. The upgrade has new features such as bar-graph displays, printed vehicle score data sheets, vehicle hardware comparisons, and access to data from several vehicle model years. AutoBid runs on most personal computers and can be used directly from a floppy drive or may be installed on a hard drive. Free copies of

AutoBid are available to interested police departments from the Law Enforcement Standards Laboratory, B116 Polymer Bldg., NIST, Gaithersburg, MD 20899, 301/975-2757. Supplies are limited. AutoBid was developed for the National Institute of Justice as part of its Technology Assessment Program.

## **NIST Seeks Halon Replacements**

NIST researchers are working with the U.S. Air Force as part of an 11-year program to find replacements for fire suppressants known as halons. Halons are used widely as fire extinguishers because they are safe, effective, and gentle to expensive and sensitive facilities such as computers and aircraft. However, these chemicals, along with chlorofluorocarbons, have been identified as contributing to the depletion of stratospheric ozone. Under an international agreement, their manufacture will be curtailed and possibly eliminated before the end of the century.

NIST scientists will develop a set of procedures to screen likely replacement candidates for a wide variety of properties, such as fire suppression efficiency, ozone depletion and greenhouse warming potential, metals corrosion, stability, and toxicity. They will identify an initial set of about 100 compounds to assess and create a database to organize past and future information about replacement candidates.

## **Materials Designed To Help Monitor Water Pollution**

Environmental agencies, as well as others studying pollution in the nation's waterways, need materials containing an

accurate composition of various compounds as a check to verify the reliability of laboratory instruments and methods. Now NIST has developed a bottled Standard Reference Material (SRM) for this purpose. It contains marine sediment with a wide range of pollutant compounds of interest to environmental scientists. The sediment material, which has certified values for 11 polycyclic aromatic hydrocarbons (PAH's), was collected from the Chesapeake Bay area near Baltimore harbor. The material also contains noncertified values for other PAH's, polychlorinated biphenyls, and chlorinated pesticides. It is available for \$241 from the Office of Standard Reference Materials, Rm. 204, Building 202, NIST, Gaithersburg, MD 20899, 301/975-6776.

## **New Method To Detect Aluminum in Blood Substitute**

Patients needing emergency blood transfusions can be given infusions of albumin as an initial replacement for blood loss. This practice eliminates the need for blood typing and can reduce the possibility of disease transfer. However, recent studies have uncovered a problem with albumin that could prompt other adverse health effects: trace levels of aluminum. In the past, aluminum was difficult to measure at these low concentrations. But now, at the request of the Food and Drug Administration (FDA), NIST researchers have developed effective methods for measuring aluminum in albumin that combine several chemical analysis techniques. Laboratories in pharmaceutical companies and hospitals can adopt these methods to screen albumin products before they are marketed or used.

NIST also has measured aluminum levels in a number of albumin samples the FDA and manufacturers will use to ensure measurement reliability.

## **Concealed Ceilings and Fire Are a Deadly Mix**

A fire in a concealed ceiling space containing combustible materials can produce up to 50 times more carbon monoxide than a fire in an open area, posing a hazard even to those remote from the fire, reports NIST. NIST experts advise that where it is impractical to remove combustible materials from these spaces, containment, fire stopping, and automatic suppression techniques need to be considered. NIST made these recommendations after investigating a fire which killed 16 people in the John Sevier Retirement Center in Johnson City, Tenn., last December. Although the fire was confined mainly to the first floor, most of the deaths were on the upper floors of the 11-story building. Tennessee state investigators reported that either a love seat or chair was the first major item to ignite. NIST researchers believe that wood-fiber tiles hidden by a suspended ceiling ignited within minutes and the fire spread rapidly, producing large amounts of carbon monoxide-laden smoke.

## **PC Database Available for Biochemists**

A new computerized database for biochemists in industrial laboratories and universities worldwide brings together for the first time all of the published information on the successful crystallization of proteins and nucleic acids. An important

research tool for the design of new drugs and chemical processes, the database is designed for personal computers. It contains crystal data and the crystallization conditions for more than 1,000 crystal forms of over 600 biological macromolecules. For each crystal entry there is a complete description of crystallization conditions and related crystallographic data. Also provided are evaluated critical data on the physical characteristics of known crystals, including unit cell parameters, space group, crystal density, and diffraction limit. NIST/CARB Biological Macromolecule Crystallization Database, Standard Reference Database 21, is available for \$300 from the Standard Reference Data Program, A323 Physics Bldg., NIST, Gaithersburg, MD 20899, 301/975-2208.

## **Electric-Field Meter Developed**

NIST researchers have developed a new isotropic, photonic electric-field meter capable of measuring continuous-wave electric fields from 10 to 15,000 volts-per-meter over a frequency range of 10 kHz to beyond 1 GHz. For pulsed fields, the minimum detectable field is 1,000 volts-per-meter. The probe uses electro-optic modulators and optical fiber leads to cause minimum perturbation of the fields being measured and to ensure immunity of the probe to electromagnetic interference. The probe's large bandwidth and its unusual ability to measure both amplitude and phase are its salient characteristics. Potential applications include electromagnetic pulse measurement, the precise measurement of any pulsed field of suitable intensity, and the measurement of fields with multiple frequency

components. For a copy of paper no. 63-69, which describes the probe, contact Jo Emery, Div. 104, NIST, Boulder, CO 80303, 303/497-3237.

## **Quantum Zeno Effect Clearly Demonstrated**

Quantum mechanics, the theory and study of matter and its interactions at the atomic level, predicts that the very act of observing a phenomenon influences the behavior of that phenomenon. NIST researchers have confirmed one aspect of this theory—that measurements of the state of a system can prevent that system from changing its state. The more frequent the measurements, the stronger the effect, they found, confirming predictions by University of Texas theorists that a continuously observed quantum system can never change its state. This is known as the quantum Zeno effect after the paradox conceived by the ancient Greek philosopher, Zeno. One consequence of the Zeno effect, which has yet to be observed, is that a continuously observed unstable system, such as a radioactive nucleus, will never decay.

The NIST experiments involved observations of a few thousand beryllium ions contained in an electromagnetic trap. A radiofrequency field was applied with the proper frequency and strength to drive the ions from one quantum state to a second one. These transitions were strongly inhibited by observations made every 4 milliseconds; when the time between observations was increased to 256 milliseconds, the transitions occurred readily. A paper describing the findings is available from Jo Emery, Div. 104, NIST, Boulder, CO 80303, 303/497-3237. Ask for paper no. 14-90.

# Lyons New Head of NIST

**O**n February 8, the U.S. Senate confirmed the appointment of John W. Lyons, a chemist and senior manager at the National Institute of Standards and Technology, to head the 89-year-old research agency. Lyons became the ninth director of NIST, succeeding Ernest Ambler who retired in March 1989. Educated at Harvard and Washington University, Lyons is one of the world's

leading authorities in fire and fire chemistry. After working for 18 years in research and development for the Monsanto Company, he came to the then-National Bureau of Standards in 1974 to create the agency's Center for Fire Research, now internationally recognized for its work in the computer modeling of fires.

Beginning in 1977, he organized and then managed the NIST National Engineering Laboratory, the largest research unit in the agency.

The author of three books and numerous technical papers, Lyons is a fellow of the American Association for the Advancement of Science and the Washington Academy of Science. He serves on the Advisory Committee for Engineering; National Science Foundation; and the Board of Visitors, College of Engineering, University of Maryland. He served as a member of the Board of Directors, National Fire Protection Association (1978-84) and ASTM

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**My top priorities  
are: to provide more  
services to  
industry . . . to provide  
technical support to  
health and safety  
services . . . and to  
contribute to progress  
in scientific and  
engineering  
research. . . .**

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(1985-86). Lyons is a member of the American Chemical Society and Sigma Xi.

His professional honors include election to the National Academy of Engineering (1985), the Presidential Rank Award of Distinguished Executive (1981), the Department of Commerce Gold Medal (1977), and the Presidential Management Improvement Award (1977). He received the 1986 Edward Uhler Condon Award for his book, *Fire*.

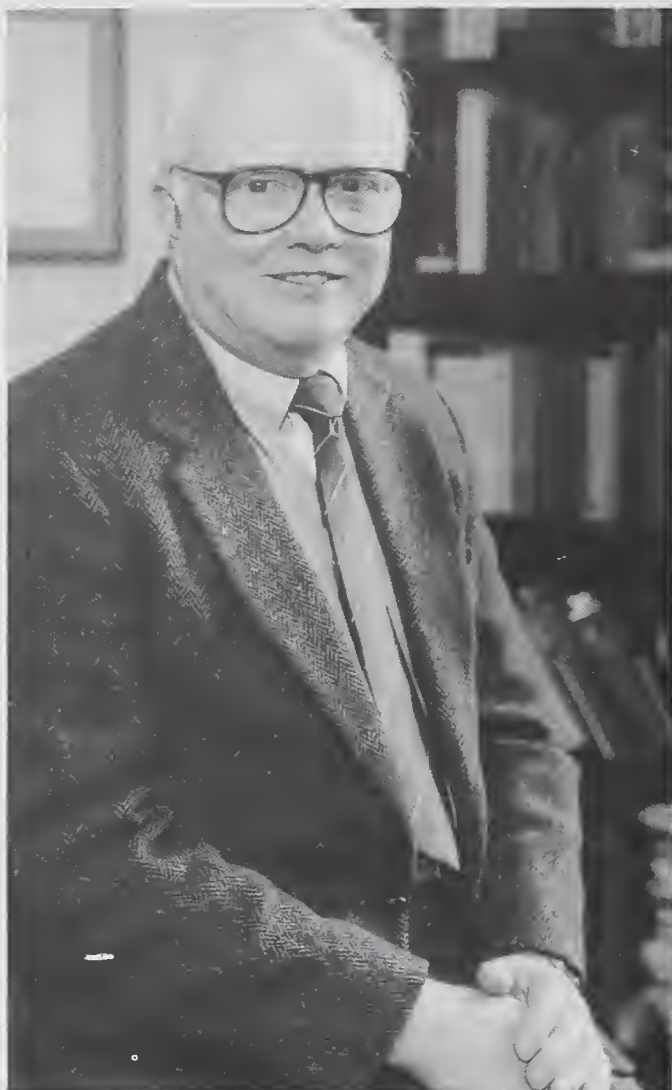
Lyons' view of NIST's future as well as its role to help industry is expressed in the following questions and answers, which were taken from the confirmation proceedings conducted by the Senate Committee on Commerce, Science and Transportation.

**Question:** What do you see as NIST's most important activities and responsibilities in the 1990's? What are your highest priorities?

**Lyons:** NIST should continue its strong research program in measurement technology necessary to support quality assurance programs in industry, but should increase its emphasis on "generic" research in newly emerging technologies. I firmly believe that a strong developing relationship between this federal laboratory and U.S. industry will be all important if we as a nation are to meet the competitive challenges of the 1990's.

My top priorities are:

■ to provide more services to U.S. industry to help improve



**John W. Lyons, NIST Director**

quality, cost, and speed of market response by focusing on additional technical support services and looking at different ways to develop generic aspects of new technologies;

- to provide technical support to a number of efforts in health and safety services where we have special capabilities; and

- to contribute to progress in scientific and engineering research through both our research and our supporting services to the research community.

**Question:** How do the research and technical services provided by NIST contribute to U.S. industrial performance and productivity?

**Lyons:** The Institute's technical services improve manufacturing practices in a number of important ways, leading to better quality and lower costs. Some examples are:

- Better process design. Design is improved by application of our reference data on materials and process fluids. The data enable the design of more cost-effective unit processes both by improving unit efficiency and by eliminating the need for overdesign to overcome the lack of accurate knowledge.

- Improved process control systems. We provide new sensors and sensing techniques, architectures for control systems, and models and protocols for communications within automated control systems.

- Integrated process automation. We are assisting industry with integration of automated machines into full systems. Our Automated Manufacturing Research Facility serves as the public testbed for new concepts in quality assurance in the automated factory of tomorrow, new control hierarchies, new interfaces, new modular structuring of the automated factory, and new devices and techniques necessary to enable the integration.

The Institute's technical services speed the movement of discoveries to the marketplace by:

- helping industry to characterize new products, for example, by determining structure of new molecules; supplying phase diagrams of new compositions, such as the high-temperature superconductors; and providing new ways to measure technical aspects of a new product, such as microdomains of magnetic materials.

- developing ways to measure the performance characteristics of new product families in their intended uses. Examples are electrical characteristics of integrated circuits, patterns and gains for antennas, toughness of advanced ceramics, and the like.

- developing the needed tests and helping secure consensus on them for establishing fair and equitable buying and selling of new products in the marketplace. We have developed over two dozen procedures for specifying optical fibers alone.

**Question:** What steps can and should NIST take to help U.S. companies improve the quality of their manufacturing and the speed with which they turn new ideas into successful commercial products?

**Lyons:** While many U.S. industrial firms are having trouble competing in the global marketplace, the United States is still extraordinarily creative and continues to build a large fraction of the first prototypes of new products. Where we are falling down

is in using our science and technology in going to market. NIST, as well as other federal technical agencies, can do something about these problems.

In general, Institute researchers work on products and process problems at the generic or precompetitive level where information is shared within the technical community. The Institute stays away from proprietary areas because we believe that they are the private sector's responsibility.

We do try to provide supporting technical services that will help industry develop products and processes, and some of these services are useful to industry at all stages of commercial development. For example, in the area of high-temperature superconductors, NIST researchers are studying how to make thin films useful in electronic devices. Someday this will be a proprietary matter, but right now we are in the generic and precompetitive stages and the community is sharing new knowledge widely.

In another case, improved process control is needed by the chemical processing industry. The processes in general are proprietary, and information is very closely guarded. The Institute works on the properties of process fluids, such as steam, and on improved sensors for measuring components of the process stream for more efficient control. The better the data, the more effective the process design, and the more efficient the process performance. Closer control in general means higher quality, fewer rejects, and lower costs.

The Institute's work in automated factory control through applications of microprocessors—computer-integrated manufacturing—has clearly shown substantial impacts on quality, cost, and speed. The computer can map errors in machines and automatically correct for them so no rejects are produced. We believe that measurements for quality assurance should be made on the process (machines), not on the products.

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**. . . the Institute  
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Keeping the variability of the machines under continuous control will guarantee quality products. This means quality measures are built into process sensing and control and will no longer be separate from the production line. A corollary is that computerized design followed by automatic programming of the computer-controlled machines on the factory floor for the first time permits industry to make design changes in products almost on the fly and to make lot sizes as small as one, economically. We are stressing these types of

programs in our planning. The results should be improved productivity and competitiveness for U.S. industry.

**Question:** What specifically do you believe NIST should do in the 1990's to help provide the tools that American industry needs (a) to spread the commercialization and reliable, cost-effective production of new emerging technologies, such as high-temperature superconductors and high-resolution displays; (b) to improve manufacturing quality; and (c) to make steady incremental improvements in both products and production processes?

**Lyons:** I believe the Institute can continue to be helpful as industry strives to improve its competitiveness. First, I believe the Institute should build on its strengths and continue to develop the supporting technical services it has traditionally provided to industry. These services—measurement techniques, data, reference materials, calibration services, protocols for software interfaces, formats for data, and proposed standards and codes—are essential to the functioning of industry and must be maintained. The demand for such services is increasing every year as the business world becomes more technically complex. So a top priority will be to continue to strengthen these areas.

For the past decade and more, we have been tying our new programs to new, advanced technologies in the belief that these technologies offer tremendous market potential in the

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future. Thus we have channeled much of our efforts into such areas as biotechnology and bioprocessing, semiconductors and superconductors, optical communications, advanced materials, automated manufacturing, computer networking, and computer security. We shall continue to concentrate on these new technologies.

We have shifted emphasis somewhat in our work from a focus on the properties and behavior of products to the manufacturing processes needed to make products. Thus, in our materials programs, we are working on how to process rapidly solidified powders into shapes as opposed simply to characterizing the powders, and how to process composites and advanced ceramics rather than just publishing data on these new materials.

Our factory automation program is entirely directed to processing. And our work on bioprocess engineering is aimed at the design problems in scaling up, from the laboratory to the factory, processes to make biochemicals such as new genetically engineered drugs. We shall continue to emphasize processing, particularly on those aspects that are generic to families of products, and we shall stay out of specific and proprietary areas.

These services are all aimed at improving the cost and quality of U.S. products. In addition, some of our services are aimed at speeding industry's response to

market changes by enabling concurrent or parallel actions in engineering and production, thereby shortening turnaround times. Often speed in responding to market demand is as important as price.

In addition to supplying technical services from our laboratory work, we also operate the new external programs assigned to us in the Technology Competitiveness Act of 1988, particularly the regional Manufacturing Technology Centers, set up to transfer manufacturing technology to small and medium-sized businesses, and the Advanced Technology Program, designed to assist U.S. business in carrying out research and development on precompetitive, generic technologies with wide commercial potential.

And we shall continue to operate the Malcolm Baldrige National Quality Award. The quality award program, which is funded by the private sector but managed by the Institute, is having a major impact on industry by increasing the motivation to look closely at quality programs and to learn how to do it better.

**Question:** What tools does NIST use to transfer its technology to industry?

**Lyons:** The Institute has worked with industry for almost 90 years. We use a variety of mechanisms to promote these interactions.

The cooperative research and development agreement is one. We have entered into about 70 of these since 1986; about 50 are in effect now. We have many other contractual arrangements covering collaborations. For example, we have about 200 industrial research associates at work at the Institute under agreements tailored for this purpose. We have hundreds of other guest workers and visiting academicians. We find all of these arrangements effective. In fact, we are very flexible in the way in which we deal with industrial collaborators.

An important point is that the Institute, unlike most other federal laboratories, is chartered to work with industry. It is our job to build partnerships to define projects jointly and to hand off the findings to the industrial clientele. We have assembled a number of small consortia of industrial firms as sponsors of specific Institute laboratory projects. Each participant puts in a few tens of thousands of dollars and gets back the results of an effort manyfold larger. This approach builds in both participation in project definition and transfer of the findings.

I believe we shall see in the years ahead many more joint endeavors between the Institute and industry in which staff and resources from both sectors are joined in research projects—some at the Institute, some elsewhere. I think we should do more—and we will.

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# President Seeks Boost for NIST in '91

**T**he Administration's FY 1991 budget request includes \$198,408,000 for the National Institute of Standards and Technology, representing a \$36.5 million increase over the current NIST appropriation and would be the largest single increase since the agency's inception. "This budget reflects the growing awareness of the vital role played by NIST in supporting our nation's

industries and commerce," according to NIST Deputy Director Raymond Kammer. "In recent years, issues of quality and competitiveness have been established as major concerns for the United States, but they have been important to this laboratory since 1901.

"These requested increases also are long overdue. Over the past 15 years, U.S. industry has increased its funding of research and development by about 82 percent, and the government's R & D funding has increased by about 57 percent. During that same period, our appropriated funding has stayed essentially flat; we are still operating on a budget from 1975," said Kammer.

Often cited as the only federal laboratory with the primary mission of aiding U.S. industry, NIST develops measurement and quality control standards and technology across a broad spectrum of scientific and industrial fields. The agency was established in

1901 as the National Bureau of Standards and rechartered in 1988 as the National Institute of Standards and Technology.

The major NIST programs that would be affected by the proposed 1991 budget address four broad areas of technology: process and quality control through chemical measurements, information technologies, electronic technology, and intelligent machines and processes. Specific areas include:

**Chemical measurements and standards**, which would be increased by \$4.33 million to develop improved measurement technology for chemical analysis. An estimated 250 million analytical chemical measurements are made daily in the United States for industrial processes or health and safety at an annual cost of \$50 billion.

**Bioprocess engineering**, which would be increased by \$2.3 million to develop the engineering data and procedures necessary

to scale laboratory developments in biotechnology up to commercially viable manufacturing processes. The United States leads the world in biotechnology research but lags seriously behind Japan and Western Europe in moving this technology into the marketplace.

**Lightwave measurement technology**, which would be increased by \$5.5 million to support accelerated development of the data and standardized measurement methods needed by the rapidly growing optical fiber and optoelectronics industries.

**Integrated Services Digital Network (ISDN)**, which would be increased by \$1 million for work on this new generation of information technology that combines voice, video, and data in a single communications technology. NIST is leading an industry-wide effort to coordinate the development of needed standards for commercial products.

**Computer security**, which would be increased by \$2.5 million to support research, standards development, and technical assistance programs for cost-effective protection of computer systems and the information they hold. Under the Computer Security Act of 1987, NIST is responsible for developing standards and guidelines for nondefense computer security throughout the federal government.

**Advanced semiconductors**, which would be increased by \$3.9 million to develop badly needed measurement support for the semiconductor industry. The next generation of integrated circuits will incorporate features with dimensions less than a micrometer, and measurements for many aspects of the new processes cannot now be made at the required accuracy. In the case of x-ray lithography, entirely new measurement techniques are needed.

**High-temperature superconductors**, which would be increased by \$1.9 million to expand NIST measurement support needed by U.S. industry to develop the commercial products using the new superconductors. With years of experience in both superconductivity and ceramics research and an unmatched combination of research facilities, NIST is in an excellent position to aid industry in this intensely competitive field.

**Atomic-scale electronics**, which would be increased by \$1 million for basic research on the fundamental physical limits on the size of integrated circuits. The research will involve measurement technology at the quantum limits of precision to support future generations of microelectronic devices based on the manipulation of individual atoms.

**Intelligent processing of materials**, which would be increased by \$1.25 million to expand collaborative work with U.S. industry to develop in-process sensors, process models, and principles of intelligent control needed for the efficient production of high-quality materials.

**Intelligent machines**, which would be increased by \$5 million to expand collaborative research with industry on sensor technology, product representation technology, and advanced control technologies for manufacturing.

**High-performance composites**, which would be increased by \$1 million to expand the NIST program in data and measurement technology for composites, an important area of worldwide competition which is hampered currently by the lack of adequate materials performance data and process controls.

The proposed NIST budget also includes two major items for the laboratory's facilities:

**Scientific computing upgrade**, an increase of \$3.122 million to upgrade and enhance computing resources at NIST.

**Retrofit of NIST facilities**, \$1 million to begin work on overhauling and retrofitting the NIST laboratories in Gaithersburg, Md. (25 years old) and Boulder, Colo. (35 years old).

The 1991 budget continues funding for two technology transfer programs. The \$10 million Advanced Technology Program will provide grants to industry-led consortia to support research in generic, precompetitive technologies. The Regional Manufacturing Technology Centers program, which provides matching grants to universities and nonprofit organizations, would receive \$5 million for use in establishing centers for the transfer of new and innovative manufacturing technology to small and medium-sized businesses.

The termination of several smaller NIST programs earmarked in the FY 1990 appropriations bill will result in savings of \$2 million. These programs include the Boehlert-Rockefeller Technology Extension Program (\$1.3 million), fire research on ignition of upholstery (\$250,000), a study of alternate refrigerants (\$250,000), and the evaluation of non-energy-related inventions (\$150,000).

*by Michael Baum  
NIST Public Affairs Specialist*

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# Looking for 'Good' Vibrations

## NIST researchers explore fast chemical reactions

**A** lot can happen in a few trillionths of a second. Billions of gasoline molecules can tear apart in an explosion that runs a car, or countless trinitrotoluene (TNT) molecules can almost simultaneously blast apart to open a mine. Scientists can now seize a trillionth of a second. Fast-pulsed lasers help them capture a chemical reaction that zips by within that fleeting moment. NIST scientists

John Stephenson, Michael Casassa, and Edwin Heilweil use laser pulses to create play-by-play recaps of virtually instantaneous chemical reactions. Their techniques reveal a new depth of detail for the kinds of combustion reactions that thrust rockets through space and the biological reactions that express the information encoded in genes.

The researchers bombard a reacting sample with laser pulses, controlling when each pulse hits the sample within one-trillionth of a second. Each pulse gives a profile of each of the chemical players at that instant.

In addition to these quick "probing" pulses, the researchers strike their samples with larger "pumping" bursts that add energy to the sample molecules. This energy excites vibrations in bonds holding the molecules together. Like connecting springs, bonds normally bounce around a

little, but the laser pulses set them off at specific rates, or frequencies, vibrating like fast-plucked violin strings. A molecule can only accept energy in quantities that set off preferred vibrations.

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**NIST scientists use laser  
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chemical reactions.**

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After adding energy with a pumping pulse, the researchers follow up with smaller probing pulses to disclose the identity of the molecules present and how much energy these carry in their vibrating bonds.

How does the probing pulse create a picture of the molecules present and their energy? The researchers send in probing pulses containing different light frequencies—which correspond to different colors—and measure those the sample absorbs. They combine the results from each frequency to create a profile of absorbed frequencies called an absorption spectrum. Scientists use such a spectrum like a fingerprint to identify atoms and molecules and see how much energy they carry.

At one time, scientists thought they could control chemical reactions by shining laser light with just the right frequencies to vibrate a particular chemical bond. That vibration would break the bond the way a bridge can collapse if shaken at its natural frequency. In general, however, scientists have found it doesn't work—exciting just the right vibration has no effect.

The reason it fails, explains Casassa, is that energy in one bond flows out into other bonds in the molecule. With their quick laser pulses, the researchers add energy to chemical bonds and track how much it dissipates each trillionth of a second.

In one of their experiments, they followed the energy dissipation as well as the reaction rate for a gas of hydrogen azide ( $\text{HN}_3$ ), as it split into an  $\text{N}_2$  and an  $\text{HN}$ . Stephenson and his colleagues received funding from the Air Force to study this reaction because it resembles the combustion of rocket fuels. The NIST researchers sent in pumping pulses that vibrated either the bond that was to break or other bonds in the molecule. Their result? Pumping different modes at comparable energy had no effect on the rate that bond broke.

Casassa explains that vibrating this bond should speed up its rate of breakage, if it weren't for one problem—energy vibrating that critical bond dispersed too quickly. "The vibration spreads out to other bonds before any chemistry takes place," he says. "Even if you carefully choose which motion you excite, you find the initial motion doesn't affect the rate of reaction because the vibrational energy sloshes back and forth between different chemical bonds."

The researchers have found exceptions. Another molecule under study, the nitrogen monoxide dimer ( $\text{ON-NO}$ ), breaks apart faster if they vibrate certain

bonds. This molecule—two NO molecules hooked together between the two N's—rapidly breaks into separate NO fragments when sparked with a boost of energy.

The researchers bombarded the NO dimer gas with pumping pulses of two frequencies, each exciting a different vibration pattern that indirectly stresses the breaking bond. One frequency stretched the two N-O bonds symmetrically, while the other vibrated those bonds antisymmetrically—so one stretched as the other compressed.

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The researchers were surprised to see that when they excited the antisymmetric stretching mode the molecule broke up 40 times faster than when they set off the symmetric mode. The result was particularly unexpected because the less energetic, lower frequency sped the reaction most. If the mode of vibration didn't matter, the higher energy laser pulse would speed up a reaction more—simply because it delivered more energy to the sample.

Why didn't the vibrations in the NO dimer dissipate too fast to change the reaction rate, as

happened with  $\text{HN}_3$ ? "The bond holding the NO arms together is weaker than the  $\text{HN}_3$  bonds," explains Casassa. "The vibrations don't couple as readily through such a weak bond."

Heilweil and his colleagues have found even more unforeseen exceptions in reactions that take place on surfaces. Surfaces of metal or glass often act as catalysts, speeding or slowing many industrial and biological reactions including those that digest food or clean up toxic exhaust gases in a car's catalytic converter.

Scientists don't fully understand how surface catalysts work. Heilweil first studied one of the better-understood systems—small glass beads with attached hydroxyl groups containing an oxygen (O) and a hydrogen (H). He shined laser light at a solution of these beads, exciting vibrations in bonds attaching the O's to the H's. The result surprised Heilweil. As in the  $\text{HN}_3$  system, he expected to see the laser energy flow from the excited bonds within a few trillionths of a second. Instead, the energy stayed isolated in this bond about 1,000 times longer.

If quick energy leakage prevented the possibility of laser-controlled reactions in other systems, could scientists make it work on surfaces like the glass beads, which isolate energy in the chosen bonds much longer? Heilweil isn't sure but agrees his results provoke further study.

He next studied reactions on metal surfaces—the most



**NIST researchers Edwin Heilweil (right) and Michael Casassa adjust the fast-pulsed laser used to study instantaneous chemical reactions.**

common sort of industrial surface reactions. He first chose models for surfaces containing just a few rhodium metal atoms and adsorbed carbonyl molecules with one carbon and one oxygen each. He discovered these systems acted much like the glass bead one. The energy he put into the carbon-oxygen bond lingered longer than expected before leaking into the metal surface.

This experiment used only six or fewer rhodium metal atoms. He got a different result using particles with more than 1,000 metal atoms. Then, energy fed directly

to the carbon-oxygen bond flowed into the surface 20 times faster. He explains that metals act differently when isolated in pieces of just a few atoms than they do in bulk. In the larger sample, electrons flow through the metal and carry the energy away better than in the smaller piece.

Heilweil plans to do similar experiments on components of DNA, the molecule that holds the genetic code. He will focus on the

actual coding elements, known as bases. Normally linked in pairs, the bonds connecting them must break for the DNA to express or reproduce its genetic code. Watching how these molecules react to lasers may reveal how their reactions work. Heilweil believes a closer look at the physics of these reactions could reveal unknown details of these reactions that underlie all life processes.

*by Faye Flam  
Washington, D.C.-area  
science writer*

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# Milestone: 500 Very Good Ideas

**A** new technique for finding oil deposits that promises to be more sensitive than conventional survey methods is the 500th invention to be recommended by the National Institute of Standards and Technology to the Department of Energy (DOE) for possible assistance in development and marketing. Through the Energy-Related Inventions Program, conducted jointly by NIST and

DOE, individual inventors and small businesses can receive practical assistance in developing and commercializing new energy-related technology. At no cost to the individual or business, NIST provides evaluations of energy-related inventions and recommends to DOE those it considers promising. In turn, DOE can provide financial support or help in moving the technology closer to the marketplace.

The 500th invention to receive NIST's recommendation is the idea of John F. Clauser of Livermore, Calif. Clauser, a research physicist, has developed a more accurate way to measure variations in gravity. This is one of the techniques geophysicists use to find rock formations that can trap oil and gas. Hydrocarbon deposits normally are found in light, porous formations, such as sandstone or limestone, that have a very different gravitational pull than heavier, denser rocks.

Clauser's gravity sensor is based upon an interferometer that uses two beams of atoms to

measure gravity variations over a certain area. When the beams recombine, an interference pattern of light and dark regions is created. The gravitational pull produced by the surrounding rock will deflect this pattern depending

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**At no cost to the individual or business, NIST provides evaluations of energy-related inventions and recommends to DOE those it considers promising.**

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upon the density of the rock. By analyzing the deflections, geophysicists can infer information concerning the underlying layers of rock formations.

"We anticipate that this proposed instrument will be 10,000 times more accurate than gravity sensors currently on the market," says George P. Lewett, chief of

the NIST Office of Energy-Related Inventions. "As a result, hydrocarbon deposits that previously went undiscovered could be identified and developed," he adds.

Of the 26,906 inventions submitted to NIST since the program started in 1975, NIST has recommended 500 for DOE assistance. For the past several years, some 100 ideas have been submitted each month. Out of these, an average of 3 to 4 have been recommended to DOE.

Another recently recommended invention is that of Vlad Hruby. His idea will help reduce the amount of particulates released into the air by processing plants such as coal-fired power-generating boilers, trash burning plants, and smelters. Hruby, president of J. Busek Co., Inc., a small research and development company in Needham, Mass., uses static electricity to form large agglomerates of dust particles that are collected more easily than individual particles.

Hruby's invention should make it economical to remove

much smaller particles than currently possible. According to Lewett, if the system performs as predicted, the invention could advance air cleaning ability significantly beyond what can now be achieved with current technology.

Many of the inventions going through the program have been introduced successfully into the market. As of December 1988, a survey of the recommended inventors showed that, at some point, 88 had sold products based on their inventions. An estimated 25 percent of the supported inventors achieve sales. Cumulative sales among this group since the start of the program exceed \$400 million.

For example, Schenectady, N.Y., inventor Ronald Brandon designed a packing ring that reduces wear and allows a tighter seal during normal operation of steam turbines that drive electrical generators in power plants. Damaged packing rings can cause energy losses of 1 to 3 percent. In 1987, Brandon entered into an exclusive worldwide licensing agreement with Quabbin Industries for manufacturing and marketing the packing rings. Recent figures show multimillion dollar sales.

Karakian Bedrosian's invention makes it possible to ship fresher-tasting produce, such as tomatoes, long distances without refrigeration. Conventional shipping in refrigerated vehicles is energy-intensive and can cause deterioration in taste and nutrition. Bedrosian, of Alpine, N.J., uses controlled atmosphere packaging to keep oxygen at a min-

imum and water vapor and carbon dioxide at desired levels. Marketed under the trade name "TomAHtoes," 909,000 boxes were shipped in 1988, with \$42.4 million in retail sales.

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### **Cumulative sales among this group since the start of the program exceed \$400 million.**

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An invention that passes an initial review undergoes a rigorous evaluation by the NIST staff in conjunction with a national network of hundreds of expert consultants from government, industry, and universities. Typically, NIST evaluators obtain written opinions from at least two consultants on each invention evaluated.

Three key questions must be answered: Is the invention technically feasible? Will it have a significant impact on the energy situation? Does it have a reasonable chance of becoming a commercial success?

If the answers to all three questions are "yes," NIST forwards it to DOE for financial support and/or other help in further development and commercialization. The one-time DOE grants typically have ranged between \$50,000 and \$200,000, with an average of \$72,000 per invention.

Inventions that are not recommended to DOE do get the benefit of a free evaluation by NIST. If an invention does not warrant further review, the key reasons are identified and reported to the

submitter of the evaluation request, who frequently continues development and tries again. "We are always willing to reconsider our position if the inventor or company can provide further details or new information," says Lewett.

The assistance the program gives to individuals and small businesses does not stop at evaluations and financial and commercialization assistance. For the past 10 years, the program has sponsored a series of National Innovation Workshops held nationwide. The 2-day workshops give practical guidance and information to inventors and entrepreneurs through lectures and panel discussions. Advice is given on turning ideas into inventions and getting help from both public and private sources.

In addition, NIST is working with individual states in their efforts to stimulate technological innovation and industrial development. In one pilot project, Small Business Development Centers (SBDC's) in 15 states are seeking out small businesses with ideas for energy-related products to submit to NIST for evaluation. If NIST finds the new technology lacks the required energy-saving potential but still has commercial promise, it is referred back to the originating SBDC with guidance to the company and the SBDC on further development.

For more information on these programs, contact the Office of Energy-Related Inventions, NIST, A115 Building 411, Gaithersburg, MD 20899.

*by Jan Kosko  
NIST Public Affairs Specialist*

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# Measuring in the Lilliputian World of Semiconductors

**N**o bigger than a fingernail, no thicker than a snowflake, semiconductor chips bring to life all kinds of electronic wonders, from computers to television sets to automobile ignition systems. These chips endow machines with the power to calculate and to remember—enabling automatic teller machines to compute your account balance, or the subway ticket reader

to judge whether you've paid enough fare.

Picture the structure on one of these chips as the streets of all the cities in the United States crowded onto a postage stamp. Unlike the clogged traffic of the cities, electric charges glide along the chip's corridors in a controlled flow that does the work of the chip. The chip (also called an integrated circuit) will work only if the manufacturers construct everything just right, like a network of streets—each with just the right width, containing just the right composition of materials, lined with just the right shapes and sizes of buildings.

On this chip cityscape, the individual streets elude the human eye, even with the aid of a conventional microscope. Manufacturers must grope through this invisible world, not knowing the dimension or composition of the circuit they produce. So many

things can go wrong that chip-makers sometimes must throw away 95 percent of their finished product.

The defective chips waste chipmakers' time and money as they roll on through the 100-step production process. For manufacturers, the key to saving money is to measure the critical properties and dimensions of chips during production, pulling bad ones out as soon as possible. The better they measure, the greater the percentage of good chips. "Measurement provides the underpinning for our ability to manufacture reliable, high-quality chips," says NIST's Semiconductor Electronics Division Chief Frank Oettinger. Measurement figures so prominently in the chip industry that companies spend about a quarter of their production costs on measurement.

NIST provides companies with the methods to measure dimensions and properties of chips. The diminishingly small dimensions on the chips challenge

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NIST scientists to develop new ways to describe and measure their intricate structure. "The detail on chips today has become so small that we are measuring things today that were almost unmeasurable just a few years

ago," says Robert Scace, Deputy Director of NIST's Center for Electronics and Electrical Engineering.

The chip itself might fit onto the little fingernail of the NIST engineer trying to measure the thicknesses, widths, compositions, or electrical properties of the individual devices. The researcher might send in small messengers—electrons or light waves—to obtain information on the chip's dimensions.

Their quest for more accurate measurement in increasingly small dimensions often brings NIST semiconductor researchers into the realm of new technology. Many of their measurement techniques help NIST and industry researchers understand and harness new developments, such as chips made from compounds other than silicon, for example, or ones that replace electric current with light waves. NIST researchers sometimes make experimental versions of such chips and other times perform measurements on ones from outside sources.

When NIST researchers develop a successful measurement technique, they often produce a certified "yardstick" called a Standard Reference Material that companies can use to check their own measurements. Companies need these Standard Reference Materials to calibrate their instruments so that a reading of a millionth of a meter or a part per billion concentration means the same thing on one company's instrument as on the next.

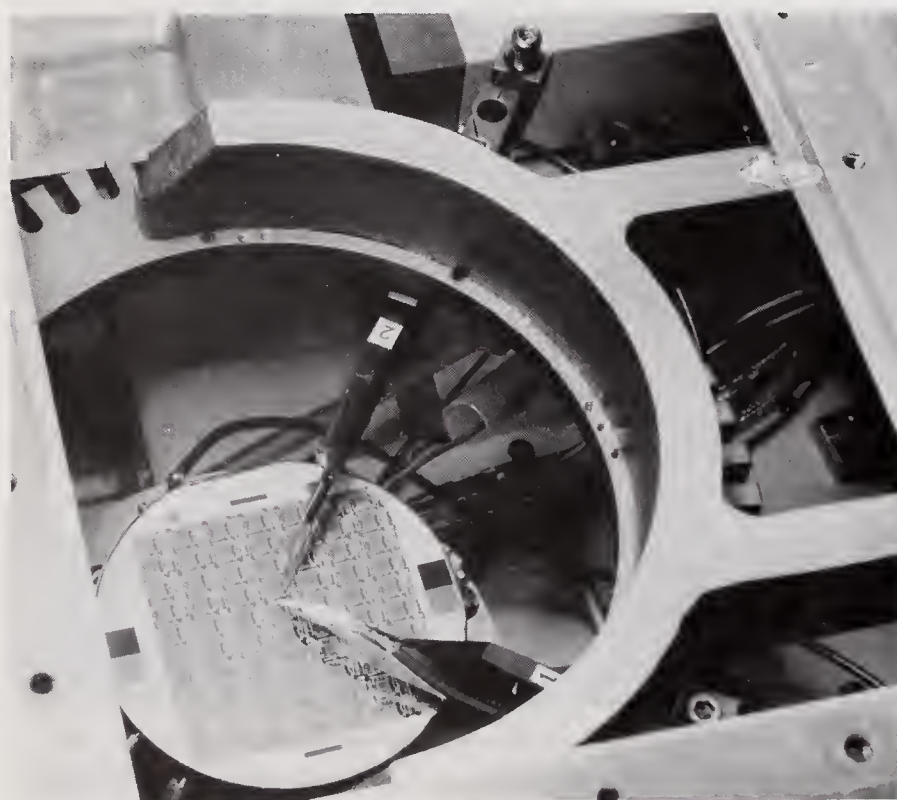
NIST devotes an entire division to semiconductor electronics. This division consists of four closely related groups—materials, processes, devices, and integrated circuit technology. NIST researchers in other areas also contribute their expertise to the semiconductor arena. Through collaborative research agreements, private companies donate equipment, researchers, and money to NIST's efforts. In addition, NIST works with SEMATECH, a government-industry consor-

employees of the U.S. electronics industry.

### **The Stuff of Chips**

Researchers in the NIST materials technology group study the substances from which semiconductor chips are made. The materials of the chip, in the form of transistors, do the actual work, controlling the flow of electric current and using this current to remember information and do calculations.

To make paths of doped material into useful circuits, the chip-



**NIST researchers use this probe for deep-level transient spectroscopic studies of defects in electronic thin films.**

tium set up to boost U.S. competitiveness through researching chipmaking technology. NIST also collaborates with the Semiconductor Research Corporation, an industry consortium set up to fund research and to train future

makers need to put just the right amounts of impurities into just the right patches. Therefore, they need to be able to measure dopant concentrations and the

electrical properties of doped regions. Manufacturers must also know about the accidental impurities and structural defects that creep into the chip during production. "As integrated circuits become more sophisticated, they require more and more exact impurity concentrations," says group leader David Seiler. "Just a bit too much or too little and the circuit won't work."

material's chemical composition and crystal structure.

One of NIST's instruments, an ellipsometer, measures thin layers of semiconductor materials. Numerous such layers stack up on a chip, with structure carved out through them.

The ellipsometer sends light into a thin layer of material and reads the reflected light to determine the material's index of refrac-

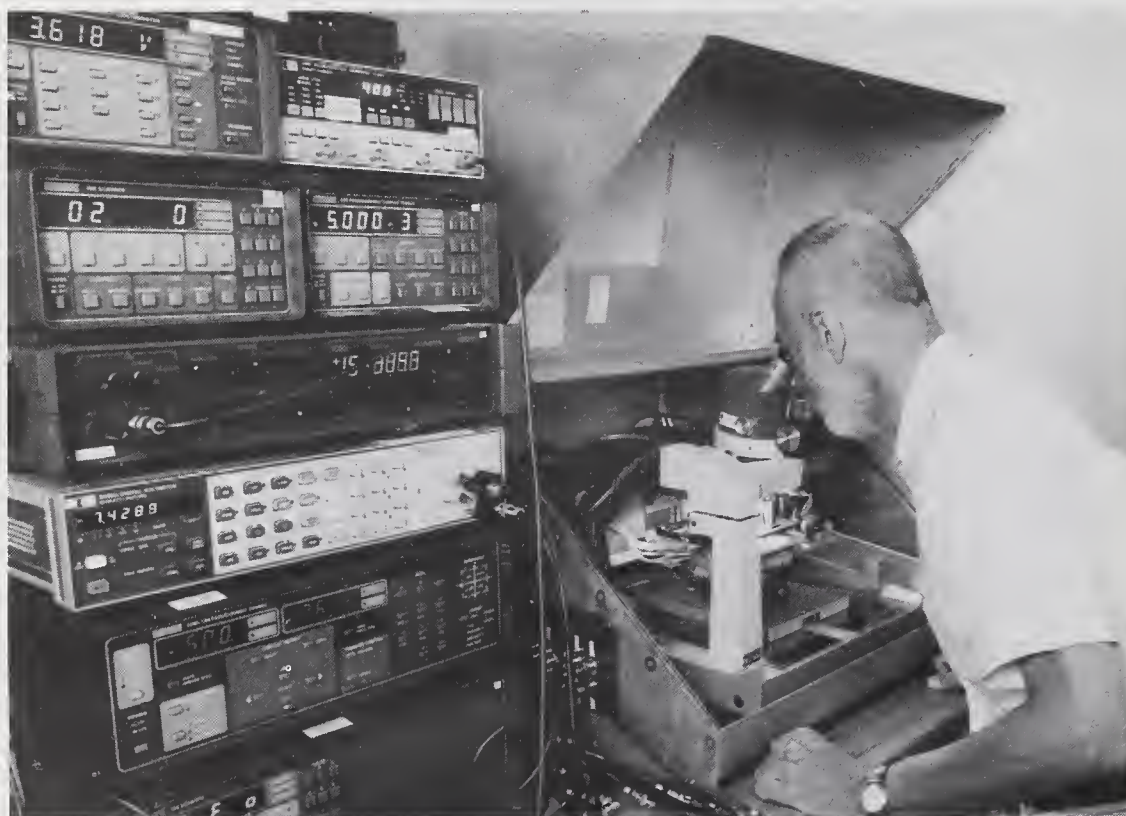
has issued a set of Standard Reference Materials, in this case samples having layers with well-defined thicknesses and indices of refraction.

### **A Hundredth of the Width of a Hair**

In NIST's Precision Engineering Division, researcher Robert Larrabee pursues the width of the streets, buildings, and bridges criss-crossing the chip and connecting its parts. These structures can be smaller than a millionth of a meter wide or 100 times thinner than a hair.

Companies need to know the width of these electrically conducting lines to prevent the lines from connecting in the wrong places and allowing the current to take a disastrous short cut, or short circuit. But these widths elude sight even with the help of ordinary microscopes, since the wavelength of light exceeds their dimensions. Larrabee shows how light reflected from a chip structure produces an erratic line with no definite edge from which to begin or end the width measurement. While use of an electron microscope—one that substitutes electrons for light—solves some of these problems, other problems are introduced.

Even perfect magnification would reveal boundaries that jut in and out like jagged sea cliffs. "How can you measure the edge when there is no definite edge?" he asks. Larrabee explains that he can more easily measure the distance between the right edges of two similar lines because he



**At the request of industry, electronics engineer Harry Schafft and his colleagues developed the technical basis for three test methods for evaluating electromigration, a serious failure mechanism in semiconductor integrated circuits.**

Some materials researchers use tiny electrical probes to measure how easily electric current can flow through stretches of the chip's circuitry. Other researchers shine light on silicon samples and read the light scattered back off to see into the ma-

tion (how much it bends light waves passing through) as well as the thickness of a layer. "Both these properties are fundamental for determining quality," says Seiler. The ellipsometry team

can define the edge of one line and measure to the corresponding point on the other. But the width of any one line depends on where he defines edges within the jagged contours of the structure. "Maybe we ought to call our work edge determination instead of width measurement," he adds.

Larrabee says most major semiconductor companies have asked him to deliver Standard Reference Materials that determine widths as narrow as one-tenth of a millionth of a meter with greater than 1 percent accuracy. "They are asking for a measurement accurate to within a few atoms," says Larrabee. "Right now, it's an impossible measurement." Though faced with such an insurmountable task today, he envisions a way to tackle these problems using better theoretical prediction. A computer will act as sleuth, taking in the available information and using scientific theory to estimate the unknown dimensions.

About a decade ago, NIST researchers achieved a major triumph over small dimensions when they developed the first accurate measurements of the widths of structures on a photomask—a tool for etching circuits on chips. The photomask works like a stencil, allowing light through certain spaces to help etch a pattern in light-sensitive chemicals. NIST, then NBS, sold companies special photomasks with slits of standard, pre-measured widths, and many companies greatly improved the accuracy of their chip dimensions as a result.

### **The Making of a Chip**

Researchers in NIST's own Semiconductor Processing Research Laboratory fabricate many of the semiconductor structures and devices that other NIST groups use to investigate, measure, and sell to private companies as Standard Reference Materials. In the processing laboratory, NIST researchers construct the intricate circuitry on semiconducting chips using the same principles that private companies use.

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Chipmaking can take more than 100 steps. First, manufacturers must prepare a mirror-finish disk, or "wafer" of crystalline silicon a few inches across, which will contain many copies of the chip. On the wafer's surface, they grow very thin layers of other materials. Then they etch the wafer with the delicate pattern of circuitry. They carve out precisely delineated spaces for dopants, with a technique akin to photography called photolithography. To do the photolithography, they must deposit layers of light-sensitive chemicals. Then, the researchers shine a light on the wafer through a photomask that

lets light through certain spaces to impart the pattern. The unexposed regions protect underlying layers, while in the exposed regions, the chip manufacturers can etch away some of these layers. They can then deposit patches of dopants to the etched-out spaces. Finally, the manufacturers divide the wafer into individual chips.

To grow very precisely controlled thin layers of semiconducting materials, researchers use molecular beam epitaxy (MBE) to build up a thin layer by shooting narrow beams of molecules, slowly growing the layer over a semiconductor surface.

NIST researchers Joseph Pellegrino and Wen Tseng say they are now using MBE to grow thin layers of the semiconducting materials gallium arsenide (GaAs) and aluminum gallium arsenide (AlGaAs). These materials sometimes replace the more abundant silicon for certain specialized uses. Unlike silicon, these other compounds can convert electrical signals to light and back to electricity again. This conversion ability may lead to optical computers and other fast-acting devices that use swifter light waves to transmit signals. By testing different GaAs and AlGaAs structures, Pellegrino and Tseng strive to help find better techniques for controlling the recipe for devices prepared from these compounds.

### **Checking the Result**

Inevitably, defects and manufacturing errors creep into semiconductor devices in the many-stage chipmaking process. Semiconductor makers expect to produce

some fraction of chips that work (the "yield") and to throw away the rest, never knowing what went wrong. NIST's integrated circuit technology group works to improve the yield by identifying the roots of defects.

The group diagnoses chip flaws using test structures—small samples of integrated circuit components that sit off to the side of the working parts. The researchers check these sample circuit elements and, with the

leader Loren Linholm. "The person on the assembly line doesn't want ten zillion bits of data," he says, "He wants to know what's wrong." To condense the overabundant data into a more usable form, he and his colleagues, Dheeraj Khera and Michael Cresswell, are collaborating with IBM on a computer system that absorbs a pile of data, weighs probabilities, and estimates the most likely causes of a processing problem. Linholm's vision of this "expert system" will digest stacks of pages of numbers and produce plain English statements like, "Your oxide layer is too thick" or "Your light exposure was uneven."

#### **Improving the Finished Devices**

How do the chips work when they are incorporated into devices? How can the devices work better? The device technology group focuses on these questions. Some of the researchers delve into the inner workings of semiconductors to create theories about the ways electric charges propagate through the devices. Others study better ways for industry to "package" chips into saleable devices. Still others work with "power" devices that regulate the electrical power channeled into homes and industries. Unlike computer chips, power devices generally carry large electric currents.

Though power devices normally handle large currents and

voltages, too much electricity can destroy them. A NIST device team has devised a new way to test the limits of power devices. Normally, in such a test, the researcher sacrifices the device. The NIST testing apparatus, however, warns of the first signs of failure and then very quickly shuts off the current before the device fails and burns out.

#### **Beating the Competition**

All these NIST projects are helping to bolster U.S. industry in the face of formidable Japanese and European competition. In 1980, Japan captured the U.S. lead in the integrated circuit business and now threatens to take over more of the market. According to Scace, the Japanese have broken ahead by constantly striving to improve their production and by risking short-term losses to achieve future advances.

NIST's measurement techniques help U.S. companies fight back by improving production and cutting costs. In supporting this work, NIST research has revealed some of the underlying physics and chemistry of semiconductor chips. With a deeper scientific understanding, manufacturers can get at the root of problems and can engineer better integrated circuits.

But as technology advances, old measuring methods grow obsolete, says Scace. With new technology come new measurement problems, which the semiconductor researchers agree should keep them busy far into the future. *F.F.*



**NIST electronics engineer David Berning developed an instrument that nondestructively tests electronic switching components found in control systems for applications ranging from the main engines of the space shuttle to automobiles.**

help of a computer, produce data revealing which parts of the process have gone awry.

However, measuring test structures can generate mountains of data, according to group

# Loma Prieta: A Primer for Public Policy

**U**nexpectedly severe damage to buildings in the San Francisco Bay area during last October's Loma Prieta earthquake underscores the lesson that structures sited on deep soil deposits need to be assessed to determine their earthquake safety, according to a study by the National Institute of Standards and Technology. "Lifelines," such as bridges, highways, and water and gas

pipelines, also are vulnerable to earthquakes and should be assessed as well, according to the NIST report.

The earthquake provided significant lessons for public policies and construction practices in the United States, said NIST. "While it was the largest earthquake to strike northern California since the great San Francisco earthquake of 1906, earthquakes of similar or larger magnitude are expected to affect 46 of the 50 states, Puerto Rico, and the Virgin Islands," the report noted.

NIST conducted the investigation at the request of Congress, bringing together a team of civil, fire safety, geotechnical, and structural engineers from various federal agencies representing the Interagency Committee on Seismic Safety in Construction.

Many of the findings reflect lessons already learned from previous quakes and research, said Richard Wright, director of the NIST Center for Building Technology, but they are important because in many earthquake-

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**. . . these damages  
occurred to structures  
located on deep  
unstable soil  
deposits. . . .**

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susceptible parts of the country structures are not designed and constructed in accord with modern seismic safety practices.

Not surprisingly, NIST found that older wood-framed dwellings and unreinforced masonry buildings which had not been strengthened sustained substantial damage. In addition, notes the NIST report, ". . . many modern buildings also have these vulnerabilities in seismically hazardous areas of the United States which have not yet, or only recently have, adopted and enforced seismic design and construction provisions in their building codes." Most structures designed in accordance with modern codes and standards

performed well without serious structural damage, said NIST.

Somewhat unexpected, however, was that many structures in the Bay area of San Francisco, 60 to 70 miles away from the earthquake's epicenter, suffered severe damage. Included were some buildings constructed using modern seismic safety practices. "At such distances, for this size earthquake, current seismic design and construction practices were expected to be capable of preventing structural damages," said the NIST report.

To a large extent, these damages occurred to structures located on deep unstable soil deposits, noted the NIST researchers. Most buildings on firmer ground sustained little or no damage.

During an earthquake, deep soil deposits over bedrock amplify some frequencies of ground motion causing the soil to act like gelatin. Such sites are common in other areas of the country that are subject to earthquake hazards. "We have seen this occurrence

before, most recently in the Mexico City earthquake in 1985," said Wright, "but this amount of damage at this distance from the earthquake was not anticipated in current seismic provisions for buildings and lifelines."

Another lesson relearned is the importance of lifelines to a community's safety and economy. But, until recently, most research on earthquake perform-

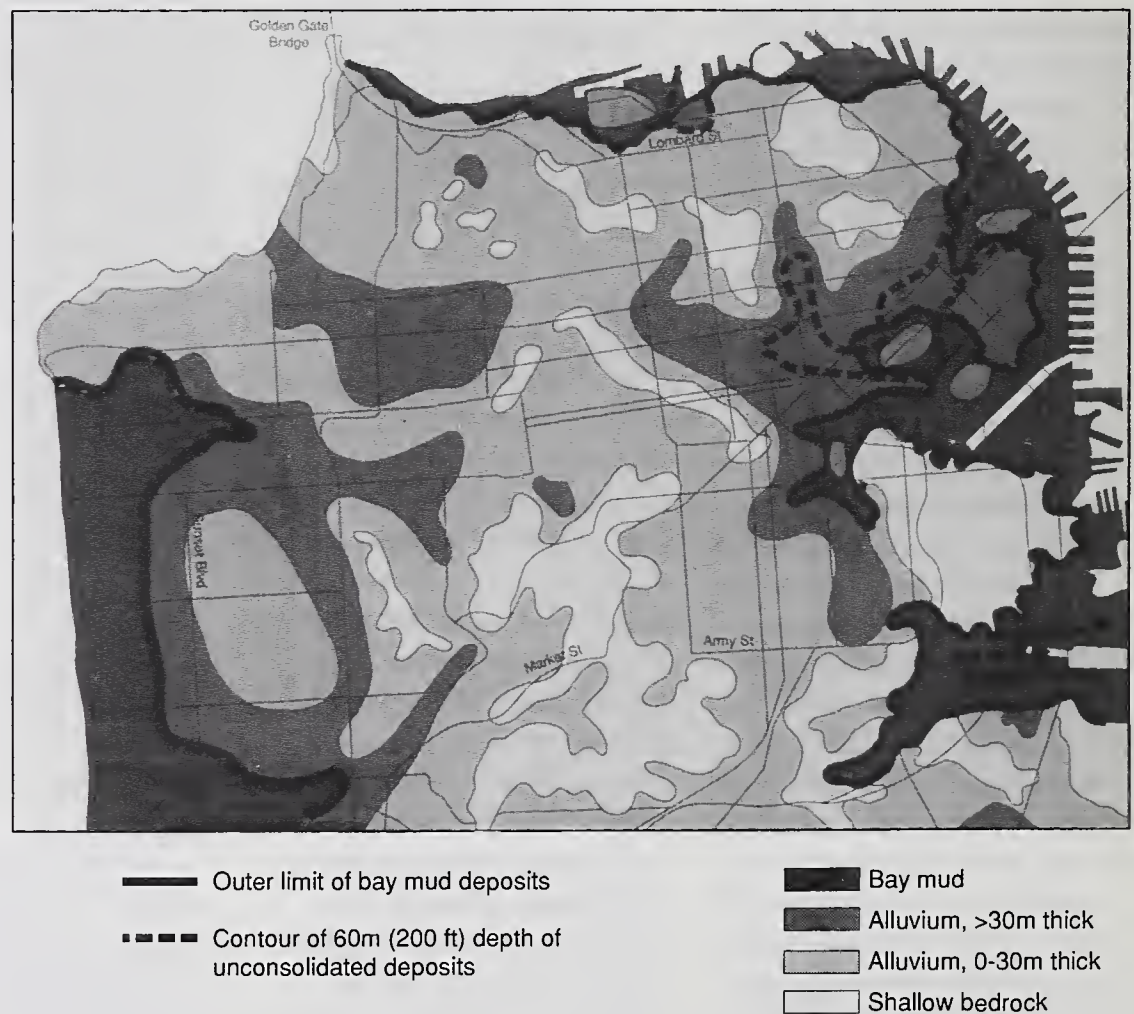
ance of structures and development of relevant design and construction practices concentrated on building construction. Improved design, assessment, and retrofit practices are needed for lifelines, said the NIST report.

The Loma Prieta earthquake caused severe damage to the area's highway network, most notably to Interstate 880 and the San Francisco-Oakland Bay

Bridge, as well as to its water and gas distribution systems. As with damage to buildings, unstable soil may have played a part in damage to lifelines, said NIST.

Like much of the U.S. highway system, I-880 was built in the 1950's and was not designed to withstand earthquake forces, said NIST. While many questions remain about precisely how I-880 failed, NIST concluded that at

**Unstable soil played a major role in the damage of buildings and "lifelines"—bridges, highways, and water and gas pipelines—during the October 1989 Loma Prieta earthquake in the San Francisco Bay area. These figures, from the NIST report, show the surface geology of the area (below) and the correlating damage (right).**



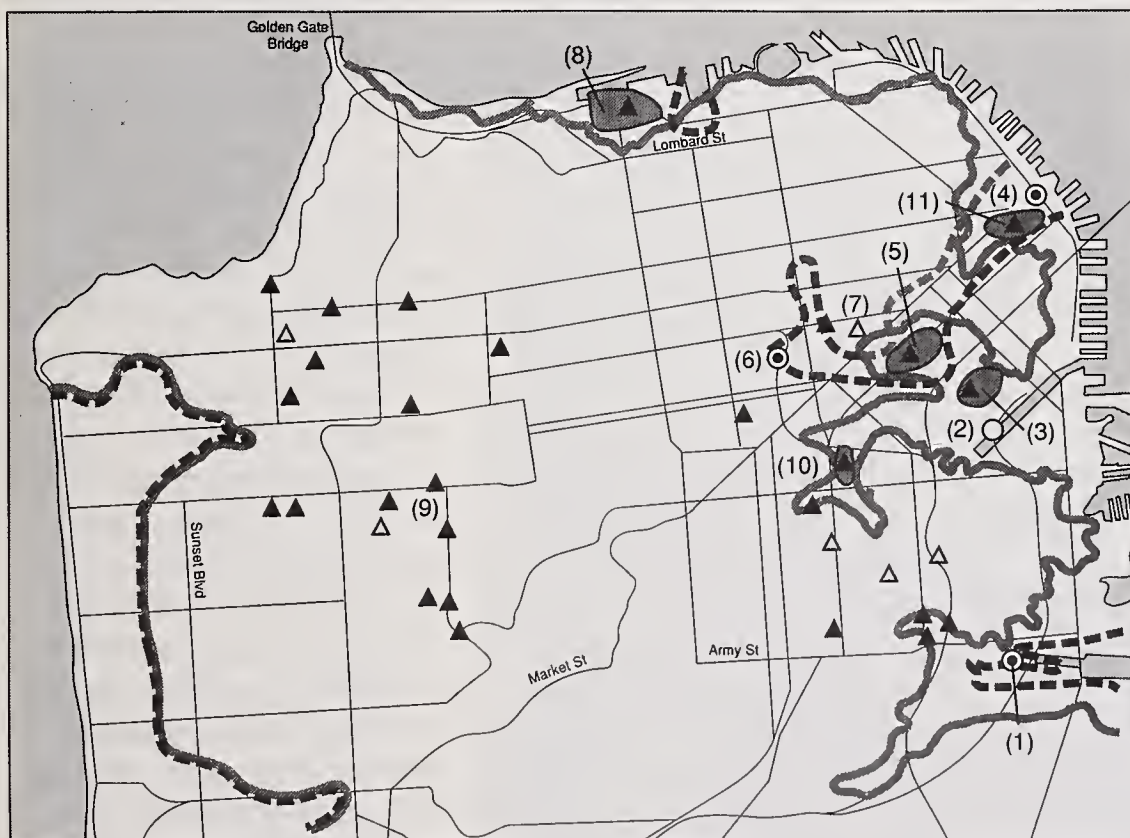
least two different factors could have contributed to its failure: strong vibrations possibly caused by amplified ground motion and inadequate confining steel in the support columns. Also, NIST determined the structure was "nonredundant," meaning a failure of a single structural component could have led to wider failure. Except for major or partial collapses at three bridge sites, including the collapse of a span of the San Francisco-Oakland Bay bridge, most of the 1,500 bridges in the area survived the earthquake with rela-

tively minor damage. During the past 15 years, most bridges and viaducts had been strengthened in the California Department of Transportation seismic retrofit program.

As part of the National Earthquake Hazards Reduction Program, established by Congress in 1977, NIST conducts research and provides technical support to the private sector and government agencies that are working to improve the performance of buildings and other structures subjected to earthquakes. Since 1971, NIST has participated in

nine earthquake investigations, including those in Mexico City in 1985 and in Armenia in 1988.

A copy of the NIST report, *Performance of Structures During the Loma Prieta Earthquake of October 17, 1989* (NIST Special Publication 778), may be purchased from the National Technical Information Service, Springfield, VA 22161 for \$31.00 (order by PB #90-184599) or from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402 for \$11.00 (order by stock no. 003-003-02988-2). J.K.



- |  |                                      |
|--|--------------------------------------|
| —— Outer limit of bay mud deposits                               | ⊙ Major damage to highway structures |
| - - - - Contour of 60m (200 ft) depth of unconsolidated deposits | ○ Minor damage to highway structures |
| ● Area of damage concentration                                   | ▲ Major damage to buildings          |
|  | △ Minor damage to buildings          |

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# More Than Just for Safety's Sake

**A**lthough safety is a motivating factor behind much of the building and fire research at the National Institute of Standards and Technology, it is not the only one. The other driving force is economics—both in helping industry to save dollars and to remain competitive in an ever-growing world market. The U.S. construction industry is losing ground to foreign competitors in both the

international and domestic markets. According to the Commerce Department's *1989 U.S. Industrial Outlook*, awards to U.S. contractors in overseas markets declined by 60 percent from 1982 to 1987. This year's edition of the *Outlook* reports that foreign-owned construction firms won \$12.7 billion in U.S. construction contracts in 1988—up from \$3.6 billion in 1982. Almost everyone will agree that technical leadership is essential to the competitiveness of this country's construction industry.

NIST research, primarily in the Centers for Building Technology and Fire Research, is helping the building industry in the United States regain its technical leadership in construction and improve its standing in the international market. "It's our job to make sure the building industry in this country is equipped with the technical tools and knowledge needed not only to produce safer structures but also to help improve the quality of construction

products and services, and, in turn, economic competitiveness," says Samuel Kramer, acting head of the NIST National Engineering Laboratory.

## **Building Open Systems**

A key element for economic strength in the international building market is "open systems" for construction products and services, says Richard N. Wright, director of the NIST Center for Building Technology. For instance, an open system permits an improved thermostat made by one firm to be used in an existing temperature control system supplied by another vendor.

As the building community increasingly relies on computers, an open system allows computers from different manufacturers to communicate. In this country, it is common for a construction team to be unique for each project. Each member of the team may have a different system of hardware and software, making it time-consuming and difficult, or even impossible, to exchange information.

At NIST, research has focused primarily on developing standards to allow specific construction-related information to be exchanged among different computers. Once completed, these standards will help make it easier to pass information among the various members of a team. Both time and money will be saved as team members can more quickly come to decisions regarding their particular construction project.

## **Better Building Blocks**

In another area, NIST researchers are developing new techniques and tools to help improve the performance, strength, and durability of building materials such as concrete. In the United States alone, billions of dollars are invested annually in millions of tons of concrete used to construct buildings, highways, dams, and bridges. The longer these last, the more the country gets for its investment. But many of these structures are deteriorating years before they should, according to a National Research Council report. That drains dollars that

could be spent elsewhere in the economy.

The NIST researchers are using computer technology combined with sophisticated techniques, such as electron microscopy and computer image analysis, to learn more about the behavior of concrete and the factors that control its strength and durability. Armed with this knowledge, they are developing computer models that ultimately may be used to predict the characteristics of concrete, such as strength and durability.

Another tool being developed at NIST uses an old technique in a new way to find flaws in concrete. Known as "impact-echo," the technique works on the same principle as the sonar pings used to locate and determine the depth of a submarine. It can be used on plain or reinforced concrete to determine where flaws are and to estimate their sizes. The research will form the basis for a simple, easy-to-use method for routine evaluation of concrete, thereby increasing the safety of concrete structures and decreasing the dollars spent on major repairs.

### **Building for Earthquakes**

Strength of concrete is a major consideration when building, especially when designing structures to resist earthquakes. As part of their work to improve the performance of buildings and other structures subjected to earthquakes, NIST researchers subjected several full-scale concrete bridge columns to earthquake-like stresses. "These tests, which are the first of their kind in the United States, are giving us

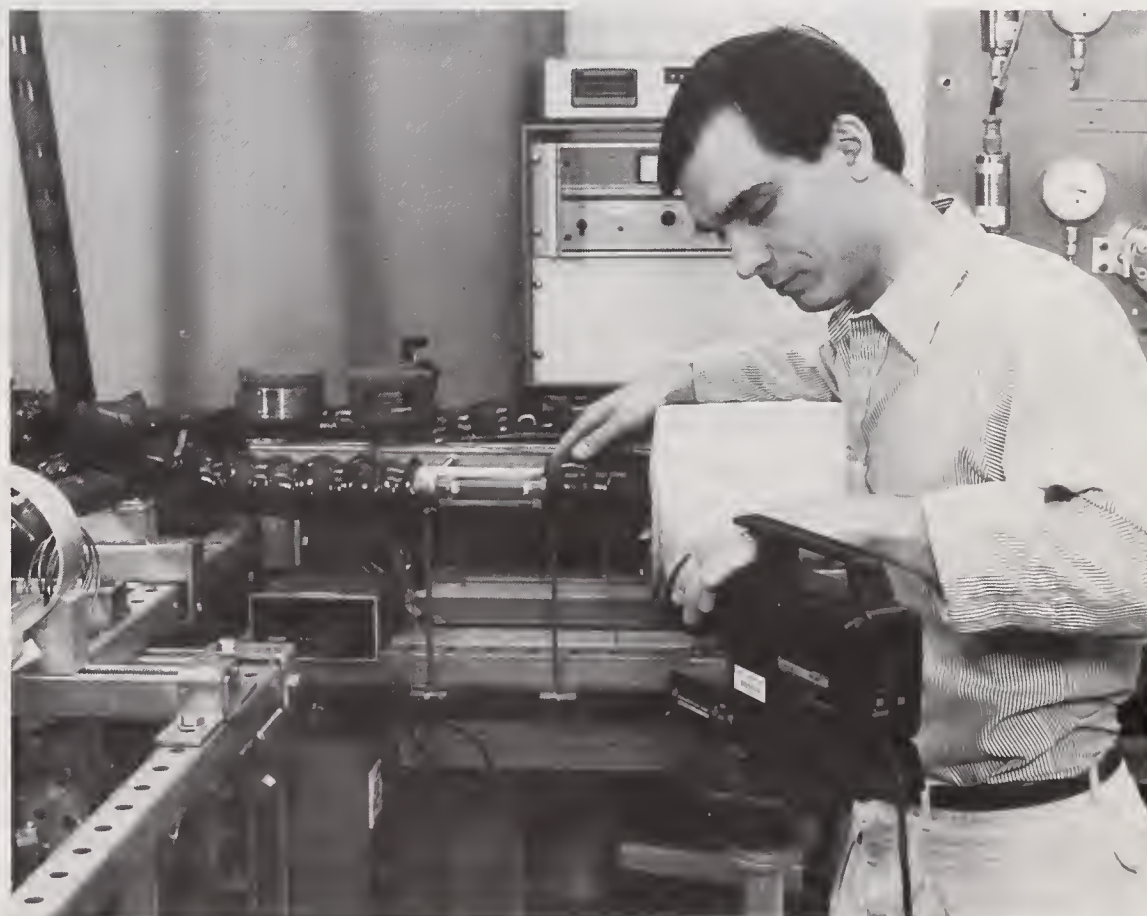
knowledge about how very large concrete structures perform during earthquakes," says Wright.

Since the test setup at NIST is unique and would be costly for industry to duplicate, a companion series of tests on smaller versions of the columns has been conducted to determine if research on small specimens can be extrapolated to the large sizes. In addition, the researchers are developing computer models which can be used to predict how these structures will hold up during an earthquake. This information will result in bridges that not only are safer but also less

costly to build if it is determined that current standards require them to be overdesigned. The National Science Foundation, Federal Highway Administration, and the California Department of Transportation helped fund this program. (See article on page 21.)

### **The Race for CFC Substitutes**

In another area, NIST is working closely with U.S. industry to help in the search for alternative chlorofluorocarbons—better known as CFC's—by developing data on the properties of likely candidates. "This information is vitally needed by industry to help



**As part of a collaborative research project at NIST, which is sponsored by the Electric Power Research Institute, mechanical engineer Mark Kedzierski studies the effects of new atmospherically safe refrigerants and refrigerant mixtures on refrigeration systems.**



**Vytenis Babrauskas, head of the NIST fire toxicity measurement group, monitors a sample in the NIST cone calorimeter, which is used to determine how furniture burns.**

evaluate possible replacements," says Wright.

Damage to the Earth's ozone layer by CFC's has industries worldwide racing to develop commercially viable substitutes as well as equipment that use them effectively. In the United States alone, more than \$100 billion worth of products rely on CFC's, including refrigerators and home insulation.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers, the Environmental Protection Agency, the Department of Energy, and

the Air Conditioning and Refrigeration Institute are helping to fund the NIST research. In addition, the Air Conditioning and Refrigeration Institute is encouraging its 170 member companies to provide refrigerant data to NIST.

The long-standing refrigerant research program at NIST also has shown that the efficiency of heat pumps and air conditioners can be increased markedly by using a mix of refrigerants.

Other NIST research includes studies on structural reliability, which can reduce design and

construction costs, and on the interaction of lighting and heating, ventilating, and air-conditioning systems—research that could result in millions of dollars being saved on lighting and air-conditioning costs. Also being looked at are techniques to predict thermal performance, which can be used as the basis for commercial computer programs for building design, and the service lives of building materials. In addition, NIST economists have developed numerous methods to help building owners and designers make economically sound

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decisions. These methods are now standard practices for the industry.

### **Reducing Fire Losses**

In an adjoining building, other NIST researchers are working to provide the scientific and engineering knowledge needed to reduce this country's fire losses—both human and economic. "Compared to other countries, the United States ranks number one in a lot of different areas," says Jack E. Snell, director of the NIST Center for Fire Research, "but when it comes to fire safety, we're near the bottom." Each year fires in the United States result in over 6,000 deaths, over 28,000 injuries, and \$7.1 billion in direct property losses; the total cost to the nation is close to \$40 billion.

To help minimize these losses and to help U.S. industry stay competitive in the world market, better tools are needed for predicting and controlling the risk of fire. For example, the loss of unique software, data, and equipment through fires could lead to economic disaster for U.S. high-technology firms competing in world markets.

### **Computer Models**

NIST, through its Center for Fire Research, is a world leader in developing computer models to simulate fires. These models give engineers, architects, building owners, and others the knowledge to improve fire safety at a reduced cost. The NIST models make it possible to duplicate real fires without having to burn a

room or building. Several models are available and some can be used on personal computers.

"These advances have launched a revolution in how fire is thought about, planned for, and confronted," says Snell.

One such model, known as HAZARD I, makes it possible to predict—under a limited set of scenarios—the spread of smoke, toxic gases, and heat from a fire in a room to other parts of a building. Among other uses, HAZARD I enables product manufacturers to examine fire scenarios that include their products. It also allows builders, architects, engineers, and fire investigators to assess fire behavior in specific building types. The NIST scientists and engineers use the models, along with other techniques, to help analyze and reconstruct fires. Recent cases include the Dupont Plaza Hotel in San Juan, a board and care residence in Sharon, Pa., the First Interstate Bank building in Los Angeles, and a retirement center in Johnson City, Tenn.

### **Materials Testing**

Other tools are being developed to help replace time-consuming and expensive full-scale tests that drive up the costs of the finished products. Traditionally, manufacturers conduct full-scale burn tests on a new piece of furniture to determine its burning behavior. As a more efficient and less costly alternative, NIST is developing small-scale measuring methods that provide even more information than the full-scale ones and at a reduced cost. For

example, an instrument known as the NIST cone calorimeter provides the data critical to predicting the fire hazard of a product from a small sample of material. The U.S.-based ASTM has adopted a voluntary fire hazard test method based on the instrument. It also is being considered as a standard test method by the International Organization for Standardization. Commercial units now are sold by five manufacturers in the United States and abroad, and a rapidly growing number are in use worldwide.

Other research includes work to develop better test methods for carpet flammability and drapery material. In addition, basic research in areas such as soot formation and polymer flammability will lead to safer materials. While much of the work emphasizes ways to prevent fires, research on sprinklers and other extinguishment systems is finding better, less expensive ways to put out fires. In work for the U.S. Department of the Interior, the NIST researchers are finding that it is possible to extinguish hazardous, costly oil well blowout fires with extraordinarily small amounts of water properly applied.

"While NIST cannot single-handedly put the U.S. building industry back on top," says Kramer, "our research, often in collaboration with industry, does contribute by improving not only building safety, but also the quality of products and services to make them more competitive." J.K.

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# Stress and Strain on the Railroad Train

**C**lickety-clack, clickety-clack, clickety-clack. . . . For some of us, that hypnotic rhythm is a nostalgic reminder of train trips in our youth; for others, it's still a significant part of daily life, commuting to and from work. But think about the source of that pulsing cadence: the impact of steel wheels on steel rail joints, 135 times a mile, mile after mile, day after day.

That's a lot of impacts, and for every passenger car, there are nearly 600 freight cars crisscrossing the continent. That makes nearly 12 million clacking steel wheels clicking along 260,000 miles of track in the United States. It all adds up to a lot of stress on the wheels: stress from loads being carried, stress from impacts on rail joints, and stress from heat.

Despite the inroads made by automobiles, trucks, and planes, the railroads remain a major component of our national transportation system, hauling coal, grain, machinery, and other goods—more than a third of the total freight moved each year by all carriers.

Most of us take the sound—and the soundness—of the wheels for granted, but not the researchers at the National Institute of Standards and Technology.

NIST is working with the Federal Railroad Administration (FRA)

to develop more reliable and efficient ways to detect high stress levels and cracks in railroad wheels. A team of scientists and engineers from the Materials Reliability Division at the NIST Boulder, Colo., laboratories, is studying the use of sound waves to determine the type and direction of stress, and the location and size of cracks.

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railroad wheels.**

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Some cracks form in the surface of the treads of railroad wheels. If the stress at a tread crack grows too large, the tread can literally peel off. NIST is developing an instrument to detect and measure these cracks,

using an electromagnetic acoustic transducer, or EMAT.

Basically, an EMAT is a device that sends ultrasonic waves into the wheel and then detects them when they return. The EMAT generates the waves electromagnetically, rather than mechanically, giving it an advantage over most other kinds of ultrasonic transducers used to detect flaws: It does not have to be in direct contact with the material being tested. The device also lends itself to situations where the material is rough or dirty.

One kind of EMAT is designed to produce a wave that travels along the surface of the tread, making up to 14 trips around the wheel. When the waves encounter a crack or other flaw, they are reflected back to the EMAT. The time it takes for the echo to return indicates the location of the crack, and the amplitude of the echo indicates its size.

The NIST team has developed a version of the EMAT sensor that can be mounted right in the rail.

That would permit each wheel to be inspected on the move, as it rolls over the sensor. Tests at the FRA facility near Pueblo, Colo., showed that the system works on trains traveling up to 15 miles per hour. Work continues on the system to improve its ruggedness for long-term use in exposed rail yards.

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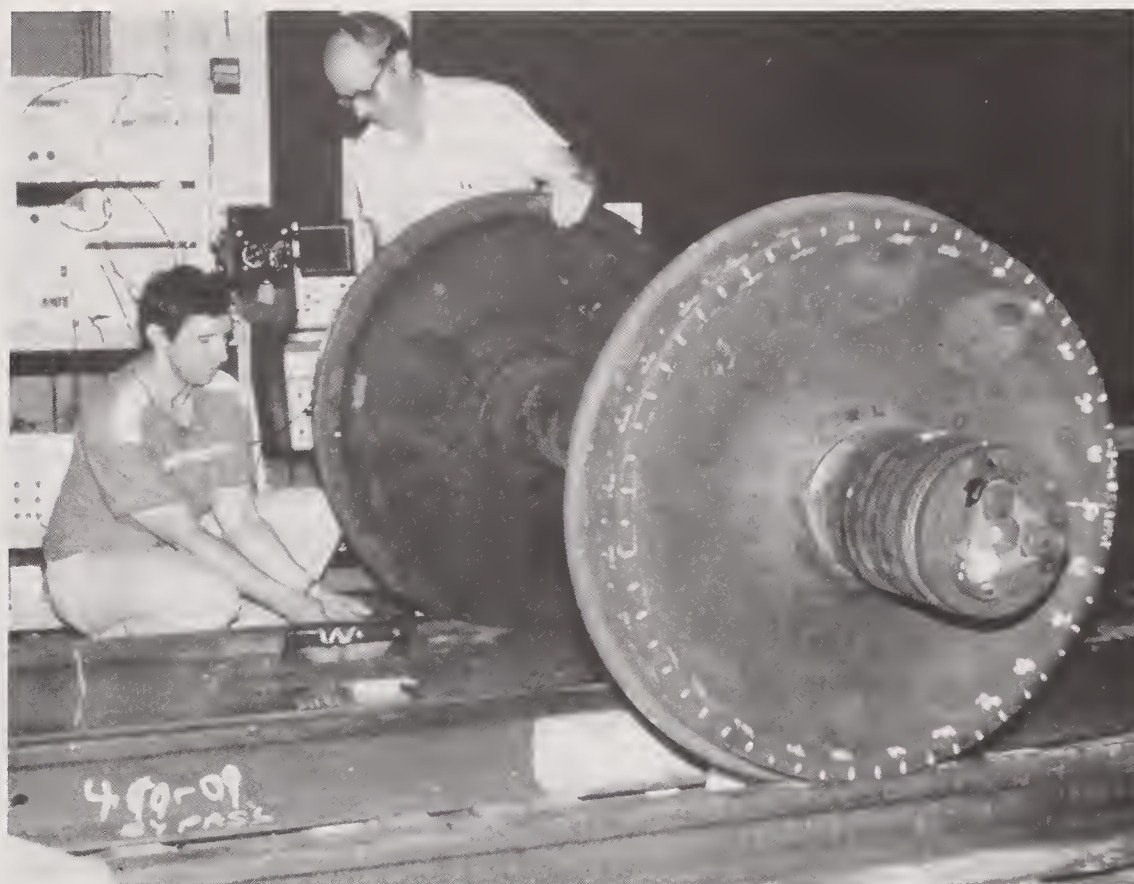
**The NIST team has developed a version of the EMAT sensor that can be mounted right in the rail.**

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A similar problem is that the heat of braking also can cause stress which adds to the residual tensile stresses from manufacturing, and eventually tiny cracks in the rim may grow and cause the wheel to fracture.

It's the job of railroad inspectors to see that wheels are inspected regularly and, if necessary, removed from service before they break and cause an accident. Despite the inspectors' efforts, according to the FRA, railroad wheel failures caused 134 accidents totaling \$27.5 million in damages over the past 4 years.

Visual inspection can spot characteristic rust patterns on the sides of wheels that indicate the wheel has been overheated by heavy braking—a condition that may result in high stress levels. But this visual rust-pattern method has a very high error rate;



**Dragan Mitraković (left), a guest researcher from the University of Belgrade, and NIST physicist Raymond Schramm inspect railroad wheels using an EMAT sensor mounted in a typical rail.**

about half the wheels removed from service turn out to have acceptably low stress levels when tested in the shop. This means that a lot of money is wasted in removing safe wheels.

When cracks in the tread, the part of the wheel that touches the rail and bears the weight of the train, are large enough, they too can be seen. But visually inspecting for such cracks is tedious, difficult, and not totally reliable—inspectors can miss some cracks that, while apparently small, actually have reached a dangerous size.

To detect this condition, polarized sound waves, which vibrate in certain directions and not

in others, are passed through the wheel's rim. The velocity of the waves changes in proportion to the amount of residual stress in the rim. Measuring the sound velocity in different directions through the wheel can give an indication of the relative amounts of stress both across the rim and around the circumference. NIST is developing an EMAT system for this task, as well.

When the work is done, the nation's railroads will have two new tools to increase safety and decrease costs.

*by Collier Smith  
NIST Public Affairs Specialist*

# New Publications

## Cooperative Research Opportunities at NIST

Natl. Inst. Stand. & Tech. (U.S.), NIST Spec. Pub. 763, 56 pages (October 1989). Order by sending a self-addressed mailing label to Office of Technology Commercialization, A343 Physics Bldg., NIST, Gaithersburg, MD 20899.

**A**lmost from the day its doors opened in 1901 as the National Bureau of Standards, NIST scientists and engineers have been working with their counterparts in industry, trade associations, universities, and other government agencies to come up with real-world solutions for real-world problems. The research partnerships with NIST can take many forms ranging from one scientist working with another on a specific problem to hundreds of organizations collaborating to develop new technology that will benefit many. Some of these joint programs last years, others months or weeks. The goal is to solve a problem efficiently, effectively, and as quickly as possible. NIST is willing to work with any organization that has a stake in helping U.S. business compete more effectively. This brochure describes briefly a sampling of almost 200 NIST research projects in which NIST would welcome collaboration with scientists and engineers from industry, universities, and other government agencies.

## Directory of U.S. Private Sector Product Certification Programs

Breitenberg, M., editor, Natl. Inst. Stand. & Tech. (U.S.), NIST Spec. Pub. 774, 235 pages (December 1989). Order by stock no. 003-003-02984-0 from GPO, \$12 prepaid.

**T**he programs and activities of 132 private-sector groups that provide product certification services are cataloged in this new revision. The directory is designed to serve the needs

of federal agencies and standards writers, as well as product manufacturers, engineers, purchasing agents, distributors, and others concerned with product-related certification procedures. The listings describe type and purpose of each U.S.-based group, products certified, standards used, certification requirements, any accreditation or recognition by a U.S. or foreign private-sector or government agency, availability of services, and method used to determine cost of services. Information is indexed by organizational name, acronyms and initials, and by products certified.

## NIST Standard Reference Materials Catalog 1990-91

McKenzie, R.L., editor, Natl. Inst. Stand. & Tech. (U.S.), NIST Spec. Pub. 260, 161 pages (January 1990). Order by sending a self-addressed mailing label to Office of Standard Reference Materials, Rm. 204 Bldg. 202, NIST, Gaithersburg, MD 20899.

**T**his catalog lists approximately 1,100 Standard Reference Materials (SRM's) available from the Institute. Materials certified for their chemical and physical properties include cements, ores, metals, glass, plastics, food, and environmental standards. Also certified are nutrition and clinical health standards to calibrate instruments that measure marijuana and cholesterol in human urine and serum, fat-soluble vitamins and cholesterol in food products, and levels of the enzyme aspartate aminotransferase (AST) to detect heart attacks. The catalog contains an alphabetical index and a complete numerical listing of the latest renewal SRM's and their certificate dates. Prices for the SRM's are published separately in annual supplements.

## Standard Reference Data Publications 1987-1989

Sauerwein, J.C., Natl. Inst. Stand. & Tech. (U.S.), NIST Spec. Pub. 708, Suppl. 2, 52 pages (December 1989). Order by sending a self-addressed mailing label to Standard Reference Data Program, A323 Physics Bldg., NIST, Gaithersburg, MD 20899.

**T**he Standard Reference Data Program, which evaluates data on the physical and chemical properties of substances, is an important part of NIST's measurement services program for science and industry. This publication updates the 1964-1984 directory of publications and computerized databases prepared through the National Standard Reference Data System (NSRDS) established in 1963. The supplement contains new information on reprints and supplements from the *Journal of Physical and Chemical Reference Data*, other NSRDS data compilations, critical bibliographies and indexes from other publishers, and databases available in printed form, on magnetic tape, disks, and through on-line computer networks.

## Quick Response Sprinklers in Chemical Laboratories: Fire Test Results

Walton, W.D., Natl. Inst. Stand. & Tech. (U.S.), NISTIR 89-4200, 55 pages (November 1989). Order by stock no. PB #90-151721/AS from NTIS, \$17 prepaid.

**D**uring a fire in a chemical laboratory, lives and property as well as critical scientific experiments are at risk within seconds. Researchers at NIST conducted a series of full-scale fire tests in chemical labs to examine the potential of quick response sprinklers to improve life safety and protect property. The tests were part of a project to help the National Institutes of Health develop sprinkler design criteria for its chemical

labs. In an unsprinklered laboratory, the NIST researchers found that within 38 seconds all of the combustible material in the lab was burning, creating lethal conditions and extensively damaging the laboratory. In contrast, both the standard and quick response sprinklers effectively controlled the fires and reduced temperatures as well as carbon monoxide and carbon dioxide levels.

### **Intelligent Processing for Primary Metals**

Cramb, A., Eckhart, Jr., W.E., Watanapongse, D., et al., editors, Natl. Inst. Stand. & Tech. (U.S.), NIST Spec. Pub. 772, 40 pages (November 1989). Order by sending a self-addressed mailing label to James Early, B309 Materials Bldg., NIST, Gaithersburg, MD 20899.

**T**his report summarizes the research agenda for the intelligent processing of steel, which was developed at a workshop sponsored by NIST, the Department of Energy, and the American Iron and Steel Institute (AISI). The agenda was developed after officials from industry, universities, and government defined the key elements producers need for the intelligent processing of steel, assessed the status of available technologies, and outlined strategies for implementing their use. Experts at the workshop recommended applying intelligent processing concepts in three generic areas: production and refining of primary metal (iron, steel, and aluminum), production of near-net shape products, and the finishing and coating of metals to yield final properties. The findings have been reviewed by an AISI advisory committee, which recommended that priorities be determined and a long-term research program be established with an industry consensus.

### **NIST Reactor: Summary of Activities—July 1988 Through June 1989**

O'Connor, C., editor, Natl. Inst. Stand. & Tech. (U.S.), NIST Tech. Note 1272, 324 pages (December 1989). Order by stock no. 003-003-02980-7 from GPO.

**T**he NIST reactor serves the needs of NIST, other government agencies, universities, and industries as a national center for the application of neutron methods to a broad range of problems of national interest. Operating at 20 MW, the reactor supports over 25 research facilities, with an additional 15 becoming available over the next 3 years as part of the cold neutron project. During the period covered by this report, over 1,160 irradiations were performed, and more than 350 researchers used the facilities. Programs range from the use of neutron beams to study the structure and dynamics of materials through nuclear physics and neutron standards to sample irradiations for activation analysis, isotope production, neutron radiography, and nondestructive evaluation.

### **1990 Directory of NVLAP Accredited Laboratories**

Trahey, N.M., Horlick, J., and White, V.R., Natl. Inst. Stand. & Tech. (U.S.), NISTIR 90-4280, 69 pages (March 1990). Order by stock no. PB #90-198920/AS from NTIS, \$17 prepaid (\$8 microfiche).

**T**his publication lists nearly 900 domestic and foreign laboratories that are accredited by the NIST National Voluntary Laboratory Accreditation Program (NVLAP) for specific test methods as of March 1, 1990. The current fields of testing are acoustics; asbestos fiber analysis; carpet; commercial products—paint, paper, plastic, and seals and sealants; computer applications; construction testing services—concrete, cement, aggregates, soil and rock,

admixtures, geotextiles, road and paving; electromagnetic compatibility and telecommunications; personnel radiation dosimetry; solid fuel room heaters; and thermal insulation.

### **Integrating Knowledge for the Identification of Cracks in Concrete Using an Expert System Shell and Extensions**

Kaetzel, L.J., Clifton, J.R., and Bentz, D.P., Natl. Inst. Stand. & Tech. (U.S.), NISTIR 89-4206, 34 pages (December 1989). Order by stock no. PB #90-151234/AS from NTIS, \$15 prepaid.

**R**emember the children's ditty, "Step on a crack, break your mother's back?" While that's not true, cracks in concrete structures are nothing to sing about. To help diagnose the causes of cracks in concrete, NIST researchers have developed a prototype expert system known as "CRACKS." An expert system is a computer program that incorporates facts along with experts' opinions and guidelines. In addition, CRACKS includes a database for maintaining information describing a structure and an "image base" for storing digitized photographs and drawings of cracking. CRACKS also can be used to measure the rate of deterioration of a structure by comparing observations over time. While CRACKS is not yet available commercially, it is available for review and comment. This report describes the system.

### **Ordering Information**

To order publications from NTIS, send the request with payment to: National Technical Information Service, Springfield, VA 22161. Publications can be ordered from GPO by mailing the order with payment to the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

# Conference Calendar

July 23-26, 1990

## Conference on Advances in Cementitious Materials

NIST, Gaithersburg, MD

Enhancing the performance of concrete can make it a more predictable material. The purpose of this conference is to advance understanding of cementitious materials to provide a rational approach to the design of new cementitious materials and composites. The fundamental science underlying the behavior of all cementitious materials will be addressed; however, to limit the scope of the conference, degradation processes will not be included. Session topics include characterization of particulate starting materials and of resultant microstructure; physical and chemical phenomena in the flow of cementitious materials prior to hardening; relationships between microstructure and physical and mechanical behavior; and interactions of water with the hardened cement paste matrix. Participants will be able to visit the laboratories of the NIST Center for Building Technology. Sponsored by NIST and the American Ceramic Society. Contact: Geoffrey Frohnsdorff, B368 Building Research Bldg., NIST, Gaithersburg, MD 20899, 301/975-6706.

August 6-9, 1990

## North American ISDN Users' Forum (NIU-Forum)

NIST, Gaithersburg, MD

Integrated Services Digital Network (ISDN) is a telecommunications technology which can be used to send and receive voice, data, and pictures simultaneously over digital telephone lines. But, for this technology to develop, user-defined applications, implementation agreements for the existing standards, and tests are needed to allow for a trans-

parent, ubiquitous, and user-driven ISDN. NIST has formed—with private industry (both manufacturers and prospective users of ISDN technology)—a forum to find ways to promote the implementation of ISDN standards in interoperable products and services, and to identify potential ISDN applications. This meeting of the forum will consist of tutorials, lab tours, demonstrations, seminars, and joint workshops for the users and implementors of ISDN technology. Sponsored by NIST. Contact: Dawn Hoffman, B364 Materials Bldg., NIST, Gaithersburg, MD 20899, 301/975-2937.

August 17-22, 1990

## International Conference on the Chemistry of Electronic Ceramic Materials

Sojourner Inn, Teton Village, Jackson, WY

Materials chemistry has evolved from the more identifiable disciplines of inorganic and solid state chemistry, ceramics, and materials science. This conference will bring together major national and international researchers to bridge the gap between those primarily interested in the pure chemistry of inorganic solids and those interested in the physical and electronic properties of ceramics. One of the primary goals of the conference will be to evaluate the current understanding of the chemistry of electronic ceramic materials and to assess the state of a field that has become one of the most important areas of advanced materials research. Sponsored by NIST, the Office of Naval Research, and NASA. Contact: Robert Roth, B126 Materials Bldg., NIST, Gaithersburg, MD 20899, 301/975-6116.

September 18-20, 1990

## Electronic Publishing '90

NIST, Gaithersburg, MD

This will be the third in a series of international conferences established to bring together researchers in all areas of electronic publishing systems. EP90 will adopt a broad definition of "electronic publishing," encompassing all aspects of computer-assisted preparation, presentation, transmittal, storage, and retrieval of documents. The scope of the conference also includes the design of the related computer systems, the design of their components, and the theory that underlies such systems. The proceedings will be published in book form and will be available at the conference. Sponsored by NIST. Contact: Lawrence A. Welsch, B252 Technology Bldg., NIST, Gaithersburg, MD 20899, 301/975-3345.

October 1-4, 1990

## 13th National Computer Security Conference

Omni Shoreham Hotel, Washington, DC

This conference provides a forum for the government and the private sector to share current information that is useful and of general interest to the conference participants on technologies, present and future, that are designed to meet the ever-growing challenge of telecommunications and automated information systems security. The focus of the conference will be on: systems application guidance; awareness, training, and education; ethics; evaluation and certification; innovations and new products; management and administration; and disaster prevention and recovery. Sponsored by NIST and the National Computer Security Center. Contact: Irene Gilbert, A216 Technology Bldg., NIST, Gaithersburg, MD 20899, 301/975-3360.



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